# NCNR

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## NG0 (DMTAS) List of Requirements

This document defines the top-level specification for a **D**oubly **F**ocusing **M**ultiplexing **T**riple **A**xis **S**pectrometer (DMTAS) at NG0 at the NIST reactor (NBSR). The document becomes effective only if all parties whose names appear below have signed it. Changes to the signed document can be initiated by each of those parties, or their replacements, at which time a new document including the proposed revision is prepared. Changes become effective only after all parties sign the new document. The old document remains part of the record.

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# Requirements for DMTAS.

## 1. Beam extraction system

### 1.1 Beam tube dimensions

The active area of the aperture at $L_a$=167 cm from the source shall be maximized within the 18.2 cm diameter available. The beam tube shall be shaped such that this active area is visible over the entire $w_m \times h_m$ = 44.1 cm x 31.5 cm area of the monochromator when it is at its closest position to the source.

### 1.2 Shutter

The beam shutter shall be outside the biological reactor shielding. It must reduce radiation incident on the monochromator sufficiently to allow extraction of the monochromator for repairs while the reactor is operating. It must also reduce radiation on the sample to less than 5 mR/hr when closed. The time to open or close shall be less than 15 sec. A clearly visible sign shall indicate the position of the shutter: Open, Closed, or travelling.

### 1.3 Pre monochromator filters

There shall be two 3-position filter exchangers immediately following the shutter. Each exchanger holds two filters with the third position being open. All filters shall be large enough to accomodate the full beam as specified in 1.1. A clearly visible sign shall indicate which filter is in place. Filter options shall be:

**1.3.1** On filter exchanger #1 : Single crystalline sapphire filter with a beam path length of 8 cm. Transmission shall be at least 75% at 3.7 meV.

**1.3.2** On filter exchanger #1: Beryllium cooled to 77 K or lower temperature. Length 10 cm transmission at least 80% at 5 meV. The filter shall be assembled from wedges separated by cadmium sheets to prevent transverse neutron propagation beyond 5 cm.

**1.3.3** On filter exchanger #2: Pyrolytic Graphite length 6 cm, ambient temperature. The c-axis shall be oriented to within one degree of the average beam direction in the beam tube.

**1.3.4** On filter exchanger #2: Unspecified. To be used in the future either for a velocity selector or for a polarizing $^3$He filter. For both devices, it will be necessary to have electrical access. The active volume shall be 20 cm long and 5 cm wider and taller than the beam.

### 1.4 Polarized neutron guide fields

Following the filters there shall be a vertical 2 mT guide field all the way to the sample.

## 2. Monochromating system

### 2.1 General Principle

The monochromator design is based on a system in which the crystal slides along the white beam, while it rotates simultaneously. At the same time a shielding drum holding a converging super-mirror guide rotates around an axis that is located on the line connecting the sample position and the current monochromator crystal axis. The sample position axis is permanently attached to this drum. The drum shall be tightly sandwiched between two saddle shields, yet be free to rotate. We denote the location of the monchromator at $2q_M = 90^0$ as the reference position. The distance from the reference position to the source, to the center of the drum, and to the sample shall be minimized while maintaining all other specifications.

### 2.2 Pre-monochromator collimators

**2.2.1** In between the filter exchanger and the monochromator translation shall be a 4-position collimator exchanger. A clearly visible sign shall indicate which collimator is in place. It shall take less than 30 sec. to exchange collimators.

**2.2.2** There shall be three different collimators, the fourth position shall be left open. All collimators shall be radial collimators with the source as their focal point. Their active area shall cover the full transverse dimensions of the beam as specified in 1.1. The spacing between blades shall be given by

$$d = a\ell \frac{L_{0r}}{L_{0r} - L_{cr}}$$

where $L_{cr}$ is the distance from the center of the monochromator at its reference position to the down stream and broadest side of the collimator, $L_{0r}$ is the distance from monochromator reference position to source, and $\ell$ is the length of the collimator blades. The effective beam divergence, $a$, shall be 20', 40', and 60' for the three collimators respectively. The transmission of the collimators shall exceed 95%.

**2.2.3** The focal point of the collimators shall coincide with the brightest part of the source to within 1 cm in the transverse direction and 10 cm in the longitudinal direction. The collimators shall be parallel to each other to within 0.03 degree. A line parallel to the central blade of any collimator shall pass through the monochromator rotation axis to within 0.5 cm. The open channel shall have the dimensions specified in 1.1 and be made from $B_4C$. LiF shall cover the reactor side of the collimators and the open channel.

### 2.3 Variable Reactor Beam aperture

As close as possible and no more than 110 cm from the center of rotation of the active monochromator shall be a slit capable of closing the reactor beam from the dimensions specified in 1.1 to $w_{min}$=3 cm and $h_{min}$=5 cm. The aperture shall be 10 cm thick, made from $B_4C$, and covered with LiF towards the reactor. The slit shall be centered with respect to the line connecting the monochromator rotation axis to the center of the source to within 0.2 cm.

**2.4 Monochromator exchanger.**

This device shall enable remote controlled selection between two different single crystal monochromator assemblies. Exchange shall take less than 1 minute. During typical operation, exchange will occur approximately once a week. The filling of this requirement may be combined with a translation stage specified in 2.1.

**2.5 Monochromating assemblies**

There will be two doubly focusing monochromators. One based on pyrolytic graphite the other based on MICA, Heussler, Silicon, or Germanium to be specified at a later stage. The mechanical assemblies for each monochromator are specified separately. It shall be possible to extract both monochromating assemblies from the instrument for service while the reactor is operating.

**2.6 Monochromator shield**

**2.6.1** Range of take-off-angles shall be 35° to 140°. It shall take less than 1 min. to change the take-off-angle from one extreme to the other. The monochromator translation stage and the drum rotation shall provide a setting accuracy of $0.03^o$ for the monochromator take off angle.

**2.6.2** Allowable radiation dose rate, and background, outside of monochromatic beam: ALARA. In addition, the instrument shall lie within an interlocked radiation exclusion zone.

**2.7 Monochromator to sample super-mirror guide.**

From monochromator to sample shall be a converging super-mirror guide with the largest practical critical angle of order $3\theta^{Ni}_c$ . The guide shall extend from as close to the monochromator as possible until 25 cm before the sample. The inside height of the guide as a function of the distance, *x*, from the sample shall be given by

$$h(x) = h_S + \left(h_m - h_s\right)\left(1 - \frac{x}{L_{1r}}\right)$$

where $h_s$=4 cm is the sample height and $L_{1r}$ is the monochromator to sample distance at the $2q_M$ =$90^o$ reference position. The sample end of the guide shall have a width of 3.2 cm and be centered with respect to the reference line that connects the sample rotation axis to the monochromator rotation axis to within 0.05 cm. The angle between the guide sides and the reference line shall be independently variable under computer controle from 0 to $2.5^o$ with an accuracy of $0.03^o$. On either side of the guide where it protrudes from the monochromator drum shall be shielding that moves with the sides of the guide to function as beam defining apertures. On the sample end of the guide this shielding shall extend until the end of the guide and on the monochromator side it shall be as long as possible. The incoherent scattering cross section of materials that are illuminated by the monochromator and visible from the sample shall be minimized.

### 2.8 Beam optics between super mirror guide and sample

The following items shall be permanently mounted just after the super mirror guide. Their total thickness shall be less than 5 cm.

**2.8.1** A monitor with a sensitivity of order $10^{-5}$ at 5 meV. The sensitivity shall be proportional to wave length.

**2.8.2** An attenuation exchanger with four positions and capable of introducing three different planar objects into the beam under computer controle. Two of the positions shall provide 10 times and 100 times attenuation respectively at 3.7 meV. These attenuators shall be permanently installed in the exchanger. The third position shall be an auxillary slot that can hold a plate with a thickness between 0.1 cm and 1 cm, width 4 cm and height 5 cm. When selected by the attenuation exchanger the plate shall be held in the center of the beam to within 0.1 cm. A clearly visible sign shall indicate the position of the attenuation exchanger.

**2.8.3** A computer controled thermal neutron aperture with variable opening from closed to the full width and height of the beam. The aperture shall be centered in the beam to within 0.05 cm and its degrees of freedom shall only be the width and height of the opening. The positioning accuracy shall be better than 0.05 cm.

## 3. Sample table

### 3.1 Location

The distance from the sample rotation axis to the monochromator rotation axis shall be minimized. When the spectrometer is in its $2q_M=90^o$ reference position this distance shall not be greater than 250 cm.

### 3.2 Degrees of freedom provided.

**3.1.1** Rotation of sample 0-$360^o$ with accuracy of 0.005 degrees.

**3.1.2** Tilt of sample table +/- $15^o$ about two mutually perpendicular horizontal axis. Accuracy better than $0.1^o$ for loads in the range specified in 3.3. The effective rotation axes shall lie within 2 cm of beam height.

**3.1.3** Elevator +/- 2 cm about beam center. Accuracy better than 0.1 cm.

**3.1.4** Horizontal translation +/- 2 cm along two mutually perpendicular horizontal directions. Accuracy better than 0.05 cm. Translation shall occur along the sample tilt axes.

### 3.3 Dimensions and load capacity.

The mounting surface shall lie at least 6" below the beam center. Minimum load capacity shall be 400 kg on axis. Max horizontal torque shall be 4 $10^2$ Nm and shall result in less than a $0.1^o$ tilt of the sample rotation axis from the vertical.

## 4. Detection system

### 4.1 Specification for detector bank as a whole:

The detection system shall consist of at least 20 identical and equidistant detection "channels" which view the sample with a relative offset in scattering angle that shall be minimized and shall not exceed $8^o$. The detection system shall cover $160^o$ in the horizontal plane.

**4.1.1** The bank of detectors must be able to rotate as a whole around the sample such that the central detector covers the range of scattering angles from $-45^o$ to $45^o$. The detector bank rotation shall be concentric with the sample rotation to within 0.05 cm. The setting accuracy shall be better than $0.01^o$

**4.1.2** The effective scattering angle detected by each channel shall be within $0.03^o$ of the nominal value

**4.1.3** It shall take less than 1 minute to rotate the detector bank between its extremal positions.

**4.1.4** The direct beam will always be incident on a part of the detector bank. Therefore, there must be a primary beam stop between the sample and the detector bank. The beam stop shall be as close to the detector bank as possible so it cannot scatter neutrons into active detection channels. The illuminated beam stop shall produce as little neutron and hard gamma radiation as possible. The width of the beam stop shall be minimized.

**4.1.5** A video camera with fluorescent plate and image intensifier shall be available to mount in front of any of the detection channels for the purpose of doing radiography of the sample region or viewing Bragg reflected beams from the sample. The sensitivity shall allow real time imaging of 10,000-500,000 neutrons per second or integrated imaging of 1000 counts per second. The width of the camera at beam height shall be minimized. The images shall be available to the main computer for analysis and printing.

### 4.2 Specification of individual detection channel:

Each detection channel shall view a 2 cm wide by 4 cm tall sample with a horizontal divergence of at least 2 degrees and a vertical divergence of $8^o$. While the filters and collimator need not be independently selectable, the final energy setting of each channel must be. Each channel shall consist of the following items:

**4.2.1** Automatic selection of 15 cm cooled BeO (77 K or colder) or 5 cm PG filter at ambient temperature. The transmission of BeO shall exceed 80% for 3.5 meV neutrons. Absorbing spacers shall prevent horizontal thermal neutron propagation by more than a channel width perpendicular to the beam.

**4.2.2** Automatic selection of 20', 40' or open channel collimation following the filter. The transmission of the collimators shall be greater than 90%.

**4.2.3** Double crystal PG(002) analyzer system covering the energy range from 2.5 meV to 15 meV. The width of the blades shall be 6 cm. The mosaic of each of the crystals shall be chosen to maximize the integrated intensity of the double analyzer for an energy resolution of 0.1 meV. The angular accuracy for rotation shall be less than $0.03^o$ and the translation stage required to move the crystals with respect to each other as the energy is changed shall have the corresponding accuracy. Analyzers shall have fixed vertical focusing optimized to minimize the size of the detector needed to achieve the specified vertical acceptance over the full energy range. It shall take less than 10 sec to change the final energy of all channels between their extreme limits and less than 2 sec to change the final energy of all analyzers by a FWHM of their energy resolution. Software shall provide a fully automated procedure to determine the zero angles for the two crystal rotation stages and the translation stage.

**4.2.4** There shall be two $^3$He detectors associated with each channel. One immediately following the first crystal and viewing the sample through the collimator. One following the second crystal. Both detectors shall have a partial $^3$He pressure and thickness to achieve 90% detection efficiency for 15 meV neutrons over the full width of the detection channel. The height of the detectors shall be minimized under the constraint that they shall be tall enough to yield $8^o$ vertical acceptance taking into account the fixed vertical focusing of the crystals.

**4.2.5** Shielding shall be sufficient to yield a fast neutron background (measured by blocking the entrance to the channel with a cadmium sheet) of no more than 30 counts per hour per channel in the second detector over the full range of incident energies and configurations of the monochromating and analyzing system. The background in the first detector shall be less than 120 counts per hour under similar conditions.

**4.2.6** The energy resolution, integrated intensity, and fast neutron background shall vary by less than 10% from channel to channel. Background and integrated intensity shall vary less than 5% and mean energy less than 5 % of FWHM resolution following continuous use of the instrument for one month.

## 5 System Wide Requirements.

**5.1** **Helium system.** A reasonable effort shall be undertaken to encapsulate all elements of the beam flight path between the cold source and the sample in a helium blanket system.

**5.2** **Hard and soft limits.** All degrees of freedom shall be equipped with soft and or hardware limits that prevent any collisions but allow the full range of angles physically achievable. Sample rotation is a special case where hardware limits must be variable because of the different constraints associated with different sample environments.

**5.3** **Automated alignment.** There shall be an automated alignment protocol for all degrees of freedom of the instrument.

**5.4** **Permanent electrical wiring.** All wiring shall be permanently installed and comply with applicable industry standards.

**5.5** The instrument will require a dedicated and integrated **software package** to plan, execute, and analyze data to take optimal advantage of the doubly focusing monochromator and the multi-channel analyzing system. Details are to be specified separately.

**5.6** **Radiation Safety Exclusion zone.** In accordance with ALARA the instrument shall be within an interlocked exclusion zone. No personnel can be in this zone when the beam is on. Details are to be specified by Health Physics.